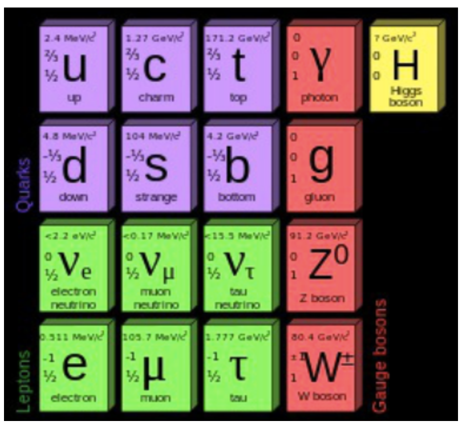
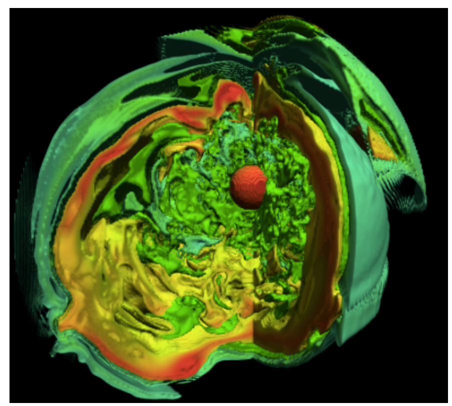
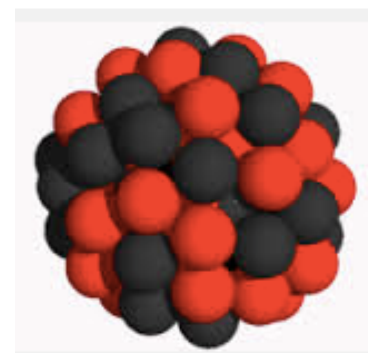
NP/HEP Connections

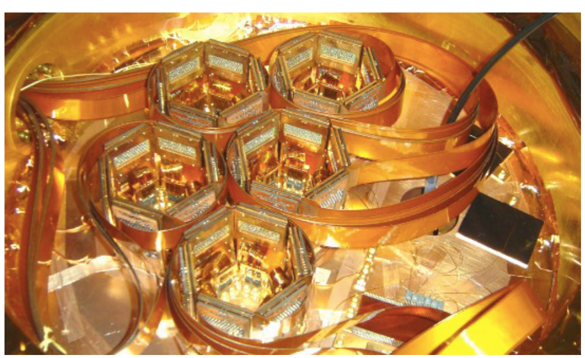
Kate Scholberg

NP Long Range Plan
Fundamental Symmetries and Neutrinos Town Meeting
Chicago, September 29, 2014

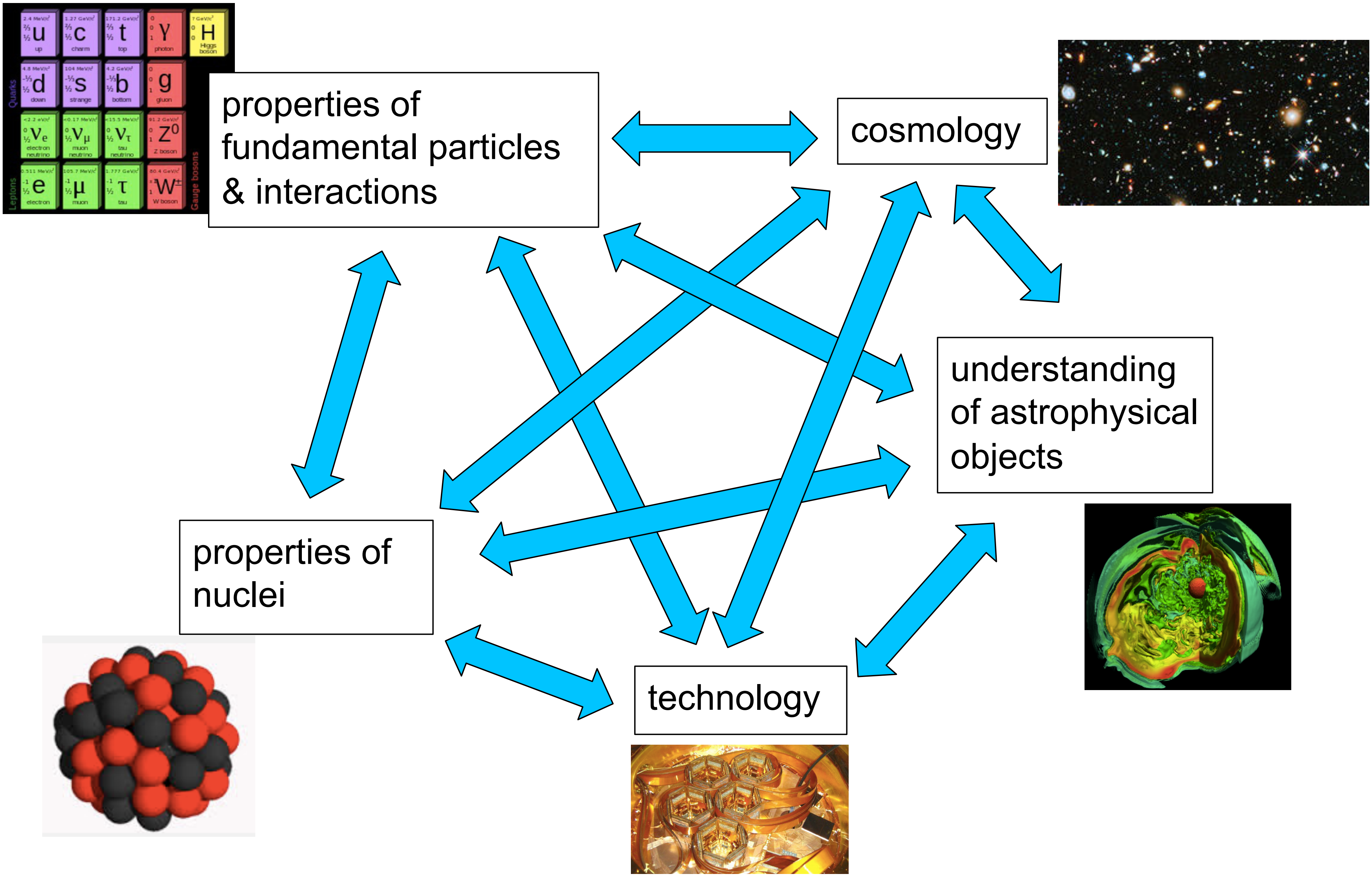


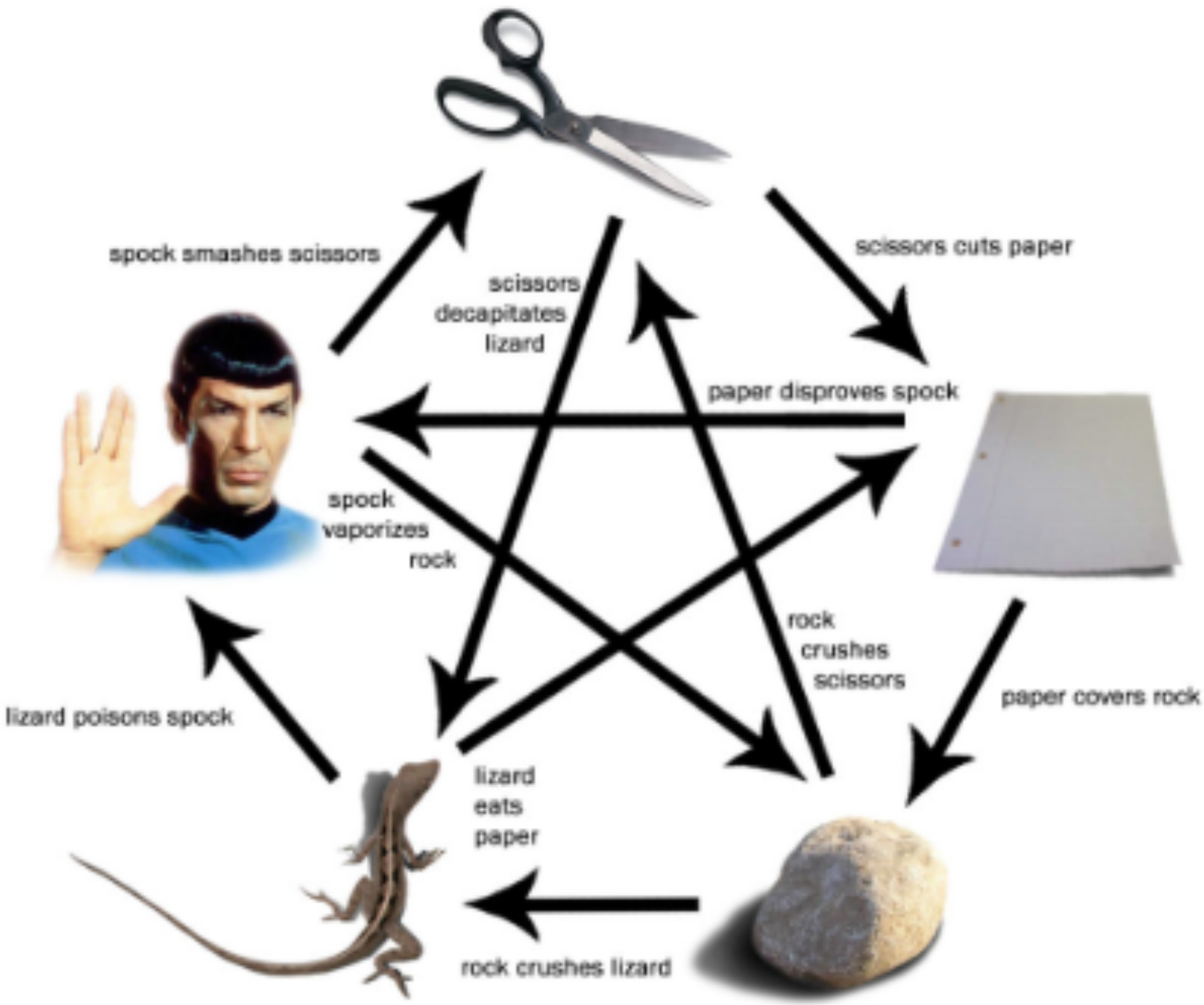






Many connections, in both science and tools...





Note: relationships are two-way, *not* like rock-paper-scissors-lizard-spock

- Brief summary of Snowmass/P5
- Highlights relevant to NP
- Some comments

slides stolen from Andy Lankford's NSAC talk

A year-long community-wide study preceded P5

Community-driven (APS DPF)

Goal: Identify compelling HEP science opportunities over an approximately 20-yr time frame

- **Not a prioritization, but made some scientific judgments**

Deliverables:

- **"White papers"**
  - **Input to working group write-ups**
- **Report:**
  - **7*x* 30-page group write-ups + theory report**
    - **w/ executive summaries input to overview**
  - **30-page Overview**

Served as invaluable input, the departure point for P5

Charge to P5

A strategic plan, executable over 10 years, in the context of a 20-year global vision

Contains 3 budget scenarios for consideration

- "… consider these scenarios not as literal guidance but as an opportunity to identify priorities and make high-level recommendations."

A. **FY2013 budget baseline: flat for 3 years, then +2% per year** (728M)

B. **FY2014 President's budget request baseline: flat for 3 years, then +3% per year** (758M)

C. **"Unconstrained" budget scenario**

   Beyond A and B, prioritize projects "… needed to mount a leadership program addressing the scientific opportunities identified by the research community."

   Identify opportunities.

Building for Discovery

Strategic Plan for U.S. Particle Physics in the Global Context

Report of the Particle Physics Project Prioritization Panel (P5)

HEPAP unanimously accepted the report on 22 May 2014

29 recommendations: here will select some relevant to this community

Criteria

Criteria were established to guide the prioritization process.

Program optimization criteria

- Science
- International context
- Sustained productivity

Individual project criteria

- Science
- Timing
- Uniqueness
- Cost vs. value
- History and dependencies
- Feasibility
- Roles

- **Recommendation 1: Pursue the most important opportunities wherever they are, and host unique, world-class facilities that engage the global scientific community.**

- **The Science Drivers**:
  - **Use the Higgs boson as a new tool for discovery.**
  - **Pursue the physics associated with neutrino mass.**
  - **Identify the new physics of dark matter.**
  - **Understand cosmic acceleration: dark energy and inflation.**
  - **Explore the unknown: new particles, interactions, and physical principles.**

NP connections everywhere, but especially here

- The **Drivers** are deliberately **not prioritized** because they are **intertwined**, probably more deeply than currently understood.
- A selected set of different experimental approaches that reinforce each other is required. **Projects are prioritized**.
- The vision for addressing each of the Drivers using a selected set of experiments is given in the report, along with their approximate timescales and how they fit together.

- **Recommendation 2: Pursue a program to address the 5 science Drivers.**

Pursue the physics associated with neutrino mass

The report recognizes the diversity of the neutrino research program.

It identifies 6 essential questions:

- **What is the origin of neutrino mass?**
- **How are the neutrino masses ordered?**
  - Oscillation experiments
- **What are the neutrino masses?**
  - Beta-decay spectrum
  - Cosmic surveys
- **Do neutrinos and anti-neutrinos oscillate differently?**
- **Are there additional neutrino types and interactions?**
  - Oscillation experiments
  - Cosmic surveys
- **Are neutrinos their own antiparticles?**
  - Neutrinoless double-beta decay

Explore the unknown:

New particles, interactions, and physical principles

Clear indicators of physics beyond the Standard Model invite exploration.

A broad-based strategy of search:

- **High energy colliders**
- **Precision physics and rare processes**
  - Baryon number violation
  - Lepton number violation
  - Muon anomalous magnet moment
  - Electric dipole moments
- **Cosmic particles**
  - Supernova neutrinos
- **Low-mass “hidden sector” particles**

examples

Principal features of the strategic plan (1/2)

- A vision that starts from the science Drivers, driven by community discussions and inputs, with criteria to guide project selection and develop a program.
- **Large projects are ordered by peak construction time:**
  - **Mu2e & g-2, high-luminosity LHC upgrades, LBNF.**
  - Order based on budget constraints, physics needs, and readiness.
  - **Enormous physics potential of the LHC should be fully exploited**, as it enters a new era with its planned high-luminosity upgrades,.
  - **U.S. should host an international world-leading neutrino program.**
    - An optimized set of short- and long-baseline neutrino oscillation experiments, with the long-term focus on the Long Baseline Neutrino Facility (LBNF).
    - The Proton Improvement Plan (PIP-II) project at Fermilab would provide the needed neutrino physics capability.
  - **Interest expressed in Japan in hosting the International Linear Collider (ILC) is an exciting development.**
    - Participation by the U.S. in project construction depends on a number of important factors, some of which are beyond the scope of P5 and some of which depend on budget Scenarios.
    - As the physics case is extremely strong, all Scenarios include ILC support at some level through a decision point within the next 5 years.

Principal features of the strategic plan (2/2)

- **Medium and small projects** in areas especially promising for near-term discoveries and in which the U.S. is in a leadership position, should move forward under all budget scenarios.
  - Second- and third-generation dark matter direct detection experiments, the particle physics components of the Large Synoptic Survey Telescope (LSST) and cosmic microwave background (CMB) experiments, and a portfolio of small neutrino experiments.
  - Another important project of this type, the Dark Energy Spectroscopic Instrument (DESI), would also move forward, except in the lowest budget Scenario.
- With a mix of large, medium, and small projects, important physics **results will be produced continuously** throughout the twenty-year P5 timeframe.
  - In our budget exercises, we maintained a small projects portfolio to preserve budgetary space for a set of projects whose costs individually are not large enough to come under direct P5 review but which are of great importance to the field.
  - This is in addition to the aforementioned small neutrino experiments portfolio, which is intended to be integrated into a coherent overall neutrino program.
- Specific investments should be made in essential **accelerator R&D** and instrumentation R&D. The field relies on its accelerators and instrumentation and on R&D and test facilities for these technologies.

Neutrino Oscillation Program

- Short- and long-baseline oscillation experiments directly probe three of the questions of the neutrino science Driver:
  - How are the neutrino masses ordered?
  - Do neutrinos and antineutrinos oscillate differently?
  - Are there additional neutrino types and interactions?

  (Note that neutrino cross-section measurements are important to oscillation program)
- There is a vibrant international neutrino community invested in pursuing the physics of neutrino oscillations.
- The U.S. has unique accelerator capabilities at Fermilab to provide neutrino beams for both short- and long-baseline experiments, with some experiments underway, and a long-baseline site is available at the Sanford Underground Research Facility in South Dakota.
- Many of these current and future experiments and projects share the same technical challenges. Interest and expertise in neutrino physics and detector development of groups from around the world combined with the opportunities for experiments at Fermilab provide the essentials for an international neutrino program.

- **Recommendation 12: In collaboration with international partners, develop a coherent short- and long-baseline neutrino program hosted at Fermilab.**

Neutrinoless Double-Beta Decay

Are neutrinos their own antiparticles? – one of the essential questions associated with the physics of neutrino mass

The questions and experiments are of "the greatest interest to particle physics".

Included in Recommendations section of the report:

Experiments that can provide essential information to particle physics are sometimes hosted by U.S. agencies other than the U.S. particle physics funding agencies (DOE-HEP, NSF-PHY).

An important example is provided by neutrinoless double-beta decay experiments,

- **which address one of the most significant questions in the neutrino Driver and**
- **which are stewarded in the U.S. by the DOE Office of Nuclear Physics, with construction contributions also from NSF Particle Astrophysics.**

Modest levels of support by the U.S. particle physics funding agencies for particle physicist participation in such experiments, as well as in experiments hosted by other nations without major U.S. construction investments, can be of great mutual benefit.

Recommendation 9: Funding for participation of U.S. particle physicists in experiments hosted by other agencies and other countries is appropriate and important

- **but should be evaluated in the context of the Drivers and the P5 Criteria and**
- **should not compromise the success of prioritized and approved particle physics experiments.**

Small Projects Portfolio

Small-scale experiments can address many questions related to the Drivers.

These experiments combine timely physics with:

- opportunities for a broad exposure to new experimental techniques,
- leadership roles for young scientists,
- partnerships among universities and national labs.

In our budget exercises, we maintained **a small projects portfolio** to preserve budgetary space for a number of these important small projects,

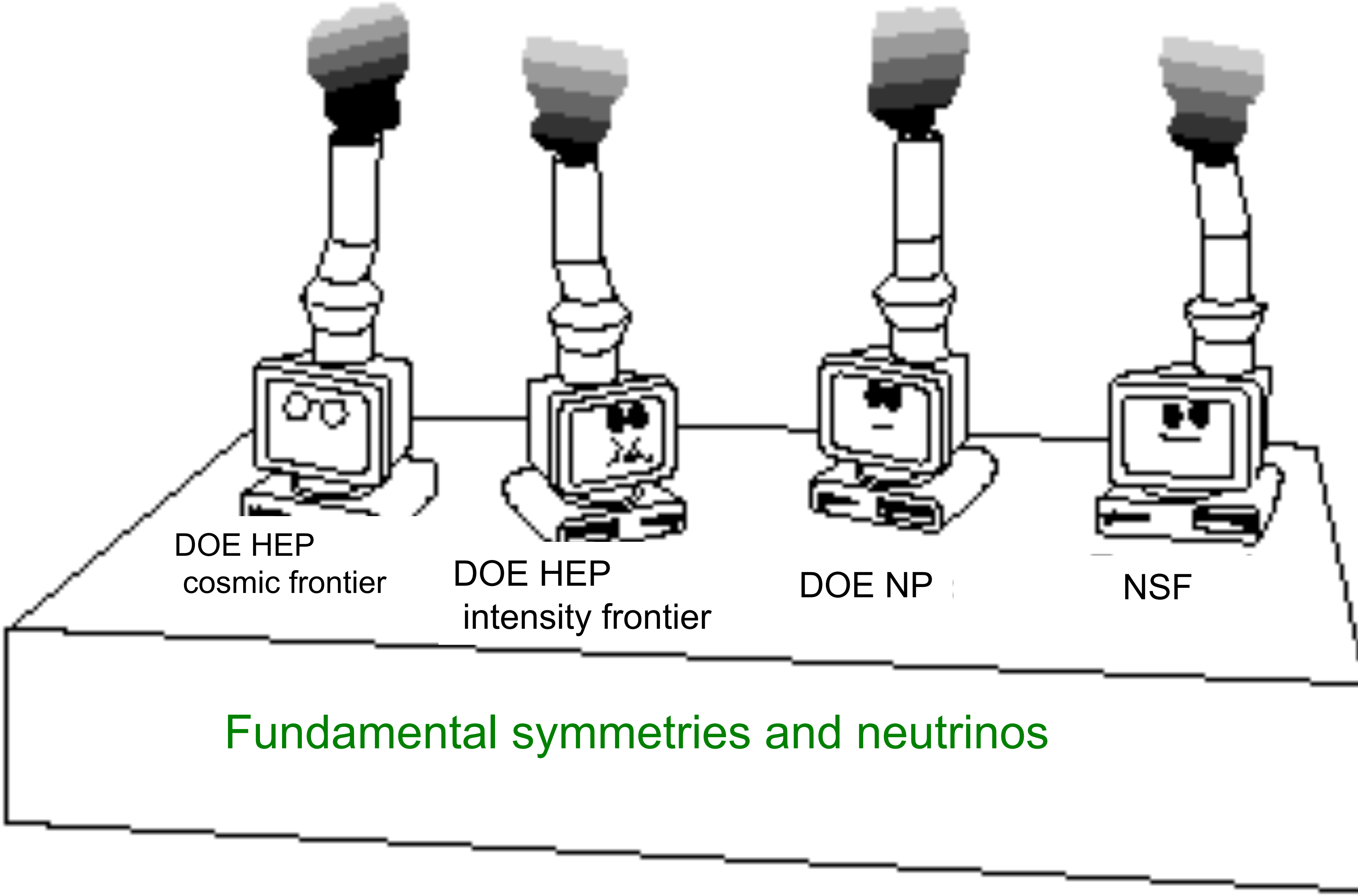
- Costs typically less than $20M.
- Projects individually not large enough to come under direct P5 review.
- Not an explicit budget line!

Many “explore the unknown” experiments fall in the small projects portfolio.

Small investments in large, multidisciplinary projects, as well as early R&D for some project concepts, were also accounted for here.

Recommendation 4: Maintain a program of projects of all scales, from the largest international projects to mid- and small-scale projects.

Comments: “stovepiping”



Question addressed by discussion panel at Snowmass Intensity Frontier Panel, April 2014

Moderator: Yuri Gershtein

Panelists: D. Cowen, R. Henning, B. McKeown, A. Piepke, M. Ramsey-Musolf, R. Roser, J. Yoo

- **How can we mitigate "stovepiping" within/between HEP and NP (DOE and NSF) that can limit opportunities for science?**

  - funding issues have been solved in the past; need constructive solutions in collaboration with agencies

From Glen Crawford:

“...it is good to encourage the community to
keep thinking about ideas
for new HEP/NP collaborative activities
and let them know the agency is receptive to such ideas.
However it may take awhile before they come to fruition.”

Conclusion

Many, many overlaps,
in both core and ancillary interests,
between this NP community (and
other NP communities for that matter) and HEP

**... we need to pay careful attention to exploit
these overlaps and make sure that
science does not get lost at the interface**

Extras/Backups

Neutrino Oscillation Program - Recommendations

Recommendation 12: **Neutrino oscillation program**

- In collaboration with international partners, develop a coherent short- and long-baseline neutrino program hosted at Fermilab.

Recommendation 13: **Long-baseline neutrino facility**

- Form a new international collaboration to design and execute a highly capable Long-Baseline Neutrino Facility (LBNF) hosted by the U.S.
- To proceed, a project plan and identified resources must exist to meet the minimum requirements in the text.
- LBNF is the highest-priority large project in its timeframe.

Recommendation 14: **Proton Improvement Plan II**

- Upgrade the Fermilab proton accelerator complex to produce higher intensity beams.
- R&D for the Proton Improvement Plan II (PIP-II) should proceed immediately, followed by construction,
- to provide proton beams of >1 MW by the time of first operation of the new long-baseline neutrino facility.

Recommendation 15: **Short-baseline neutrino experiments**

- Select and perform in the short term a set of small-scale short-baseline experiments that can conclusively address experimental hints of physics beyond the three-neutrino paradigm.
- Some of these experiments should use liquid argon to advance the technology and build the international community for LBNF at FNAL.

Accelerator R&D

Advances in particle physics require advances in accelerator technology,
which demands an aggressive, sustained, and imaginative R&D program.
Experience suggests this R&D will also have large, positive impacts beyond particle physics.

Recommendation 23:
Support the discipline of accelerator science
through advanced accelerator facilities and
through funding for university programs.
Strengthen national laboratory-university R&D partnerships,
leveraging their diverse expertise and facilities.
(This recommendation has important workforce development implications.)

Recommendation 26:
Pursue accelerator R&D with high priority
at levels consistent with budget constraints.
Align the present R&D program with the P5 priorities and long-term vision,
with an appropriate balance among
generic R&D, directed R&D, and accelerator test facilities
and among short-, medium-, and long-term efforts.
Focus on outcomes and capabilities that will dramatically improve cost-effectiveness for mid-term and far-term accelerators.

Explore the unknown - 2

Baryon number violation

- Nucleon instability
  - Report calls for a significant improvement in discovery sensitivity over current searches for proton decay as a requirement for LBNF.
- Neutron-antineutron oscillation
  - NNbarX as an example – concept with large construction scope but small near-term R&D request -> small project portfolio

Charged lepton number violation

- Muon-to-electron conversion:
  - Mu2e project recommended for completion.
- Tau lepton decays: LHCb & Belle II -> small projects portfolio

Explore the unknown - 3

Muon anomalous magnetic moment (g-2)

- g-2 at Fermilab recommended for completion

Electric Dipole Moments (EDM's)

- Extremely sensitive probe of new physics that does not conserve CP
- Considerable discussion at Snowmass
- Storage Ring Proton EDM experiment (Fermilab) – concept with large construction scope but small near-term R&D request -> small project portfolio

Supernova neutrinos

- Report calls for a demonstrated capability to search for supernova bursts as a requirement for LBNF.
- (LBNF liquid-argon neutrino detector will be sensitive to neutrinos, as opposed to anti-neutrinos.)

Low-mass hidden-sector particles

- *E.g.* dark photons -> small project portfolio

Improvements to Fermilab proton complex will improve future capabilities.

Significant Changes in Direction

- Increase investment in construction.
  - In constrained scenarios, this implies increased <u>fraction</u> of budget toward construction.
- Reformulate the long-baseline neutrino program as an internationally designed and funded program, with Fermilab as host.
- Upgrade the Fermilab proton accelerator complex to produce the world's most powerful neutrino beam
  - redirecting Project-X activities & some existing accelerator R&D
- Proceed immediately with a broad second-generation (G2) dark matter direct detection program.
  - Invest at level significantly above that called for in 2012 joint agency announcement.
- Provide increased particle physics funding of CMB research & projects,
  - as part of the core particle physics program, in context of multiagency partnerships.
- Re-align activities in accelerator R&D, which is critical to enabling future discoveries, based on new physics information and on long-term needs.
  - Reassess the Muon Accelerator Program (MAP), and consult with international partners on the early termination of MICE (Muon Ionization Cooling Experiment).
  - In the general accelerator R&D program, focus on outcomes and capabilities that will dramatically improve cost effectiveness for mid- and far-term accelerators.

Table 1
Summary of Scenarios

Project/Activity	Scenarios: Scenario A	Scenario B	Scenario C	Science Drivers: Higgs	Neutrinos	Dark Matter	Cosm. Accel.	The Unknown	Technique (Frontier)
Large Projects									
Muon program: Mu2e, Muon g-2	Y, Mu2e small reprofile needed	Y	Y					✓	I
HL-LHC	Y	Y	Y	✓		✓		✓	E
LBNF + PIP-II	Y, LBNF components delayed relative to Scenario B.	Y	Y, enhanced		✓			✓	I,C
ILC	R&D only	R&D, possibly small hardware contributions. See text.	Y	✓		✓		✓	E
NuSTORM	N	N	N		✓				I
RADAR	N	N	N		✓				I

TABLE 1 Summary of Scenarios A, B, and C. Each major project considered by P5 is shown, grouped by project size and listed in time order based on year of peak construction. Project sizes are: Large (>$200M), Medium ($50M-$200M), and Small (<$50M). The science Drivers primarily addressed by each project are also indicated, along with the Frontier technique area (E=Energy, I=Intensity, C=Cosmic) defined in the 2008 P5 report.

Project/Activity	Scenario A	Scenario B	Scenario C	Higgs	Neutrinos	Dark Matter	Cosm. Accel.	The Unknown	Technique (Frontier)
	Scenarios			Science Drivers					
Medium Projects									
LSST	Y	Y	Y		✓		✓		C
DM G2	Y	Y	Y			✓			C
Small Projects Portfolio	Y	Y	Y		✓	✓	✓	✓	All
Accelerator R&D and Test Facilities	Y, reduced	Y, some reductions with redirection to PIP-II development	Y, enhanced	✓	✓	✓		✓	E,I
CMB-S4	Y	Y	Y		✓		✓		C
DM G3	Y, reduced	Y	Y			✓			C
PINGU	Further development of concept encouraged				✓	✓			C
ORKA	N	N	N					✓	I
MAP	N	N	N	✓	✓	✓		✓	E,I
CHIPS	N	N	N		✓				I
LAr1	N	N	N		✓				I
Additional Small Projects (beyond the Small Projects Portfolio above)									
DESI	N	Y	Y		✓		✓		C
Short Baseline Neutrino Portfolio	Y	Y	Y		✓				I

TABLE 1 Summary of Scenarios A, B, and C. Each major project considered by P5 is shown, grouped by project size and listed in time order based on year of peak construction. Project sizes are: Large (>$200M), Medium ($50M-$200M), and Small (<$50M). The science Drivers primarily addressed by each project are also indicated, along with the Frontier technique area (E=Energy, I=Intensity, C=Cosmic) defined in the 2008 P5 report.

Figure 1
Construction and Physics Timeline

FIGURE 1 Approximate construction (blue; above line) and expected physics (green; below line) profiles for the recommended major projects, grouped by size (Large [>$200M] in the upper section, Medium and Small [<$200M] in the lower section), shown for Scenario B. The LHC: Phase 1 upgrade is a Medium project, but shown next to the HL-LHC for context. The figure does not show the suite of small experiments that will be built and produce new results regularly.

Scenario C

- The U.S. could move boldly toward development of transformational accelerator R&D.
  - Change the capability-cost curve of accelerators.
  - Newly formed HEPAP Subcommittee on Accelerator R&D to provide detailed roadmap.
  - As work proceeds worldwide on long-term future-generation accelerator concepts, the U.S. should be counted among the potential host nations.
- Should the ILC go forward, Scenario C would enable the U.S. to play world-leading roles in the detector program as well as provide critical expertise and accelerator components.
- The U.S. could offer to host a large water Cherenkov neutrino detector to complement the LBNF liquid argon detector
  - Take full advantage of the world's highest intensity neutrino beam. This approach would be an excellent example of global cooperation and planning.

Neutrino Oscillation Program

- Short- and long-baseline oscillation experiments directly probe three of the questions of the neutrino science Driver:
  - How are the neutrino masses ordered? Do neutrinos and antineutrinos oscillate differently? Are there additional neutrino types and interactions?
- There is a vibrant international neutrino community invested in pursuing the physics of neutrino oscillations.
- The U.S. has unique accelerator capabilities at Fermilab to provide neutrino beams for both short- and long-baseline experiments, with some experiments underway, and a long-baseline site is available at the Sanford Underground Research Facility in South Dakota.
- Many of these current and future experiments and projects share the same technical challenges. Interest and expertise in neutrino physics and detector development of groups from around the world combined with the opportunities for experiments at Fermilab provide the essentials for an international neutrino program.

- **Recommendation 12: In collaboration with international partners, develop a coherent short- and long-baseline neutrino program hosted at Fermilab.**

Long-baseline Neutrino Program

- The long-baseline neutrino program plan has undergone multiple significant transformations since the 2008 P5 report.
  - Formulated as a primarily domestic experiment, the minimal CD-1 configuration with a small, far detector on the surface has very limited capabilities.
  - A more ambitious long-baseline neutrino facility has also been urged by the Snowmass community study and in expressions of interest from physicists in other regions.
- To address even the minimum requirements specified above, **the expertise and resources of the international neutrino community are needed.**

- **A change in approach is therefore required**:
  - The activity should be reformulated under the auspices of a new international collaboration, as an internationally coordinated and internationally funded program, with Fermilab as host.
  - There should be international participation in defining the program's scope and capabilities.
  - The experiment should be designed, constructed, and operated by the international collaboration.
  - The goal should be to achieve, and even exceed if physics eventually demands, the target requirements through the broadest possible international participation.

Requirements of a long-baseline neutrino facility

- **Goal**: P5 set as the goal:
  - **mean sensitivity to CP violation of >3σ over >75% of the δ_{CP} range**
  - Based on the science Driver and what is practically achievable in a major step forward
  - By current estimates, this goal corresponds to an exposure of **600 kt*MW*y** assuming systematic uncertainties of 1% and 5% for the signal and background, respectively.
    - With a **wideband neutrino beam** produced by a proton beam with power of **1.2 MW**, this implies a far detector with fiducal mass of **>40 kilotons (kt) of liquid argon (LAr)** and a **suitable near detector**.

- **Minimum requirements:**
  - Identified capability to reach an exposure of at least 120 kt*MW*yr by the 2035 timeframe,
  - Far detector situated underground with cavern space for expansion to at least 40 kt LAr fiducial volume, and
  - 1.2 MW beam power upgradable to multi-megawatt power.
  - Demonstrated capability to search for:
    - supernova (SN) bursts and
    - proton decay,
      - providing a significant improvement in discovery sensitivity over current searches for the proton lifetime.

Long-Baseline Neutrino Facility (LBNF)

- Key preparatory activities will converge over the next few years:
  - International reformulation,
  - PIP-II design and project definition,
  - Necessary refurbishments to Sanford Underground Research Facility.
  - Together, these will set the stage for the facility to move from the preparatory to the construction phase around 2018.
    - The peak in LBNF construction would occur after HL-LHC peak construction.

- **Recommendation 13:**
  - **Form a new international collaboration to design and execute a highly capable Long-Baseline Neutrino Facility (LBNF) hosted by the U.S.**
  - **To proceed, a project plan and identified resources must exist to meet the minimum requirements in the text.**
  - **LBNF is the highest-priority large project in its timeframe.**

Proton Improvement Plan II (PIP-II)

- The PIP-II project at Fermilab
  - a necessary investment in physics capability,
    - enabling the world's most intense neutrino beam,
    - providing the wideband capability for LBNF,
    - as well as high proton intensities for other opportunities,
  - an investment in national accelerator laboratory infrastructure.
  - The project has already attracted interest from several potential international partners.
- **Recommendation 14:**
  - **Upgrade the Fermilab proton accelerator complex to produce higher intensity beams.**
  - **R&D for the Proton Improvement Plan II (PIP-II) should proceed immediately, followed by construction,**
  - **to provide proton beams of >1 MW by the time of first operation of the new long-baseline neutrino facility.**

Short-Baseline Neutrino Oscillation Program

- Hints from short-baseline experiments suggest possible new non-interacting neutrino types or non-standard interactions of ordinary neutrinos.
- These anomalies can be addressed by proposed experiments with neutrinos from radioactive sources, pion decay-at-rest beams, pion and kaon decay-in-flight beams, muon-decay beams, or nuclear reactors.
- A judiciously selected subset of experiments can definitively address the sterile-neutrino interpretation of the anomalies and potentially provide a platform for detector development & international coordination toward LBNF.
  - The short-term short-baseline science and detector development program and the long-term LBNF program should be made as coherent as possible in an optimized neutrino program.

- **Recommendation 15:**
  - **Select and perform in the short term … a set of small-scale short-baseline experiments … that can conclusively address experimental hints of physics beyond the three-neutrino paradigm.**
  - **Some of these experiments should use liquid argon to advance the technology and build the international community for LBNF at FNAL.**

LHC (Near-term & Mid-term High-energy Colliders)

- The enormous physics potential of the LHC, entering a new era with its planned high-luminosity upgrades, should be fully exploited.
- LHC and its upgrades,
  - The nearest-term high-energy collider,
  - A core part of the U.S. particle physics program,
  - With unique physics opportunities addressing 3 of the 5 Drivers (Higgs, New Particles, Dark Matter).
- The Phase-2 luminosity upgrade (HL-LHC)
  - Encompasses both the general-purpose experiments (ATLAS and CMS) and the accelerator;
  - Required to fully exploit the physics opportunities offered by the ultimate energy and luminosity performance of the LHC.
- U.S. contributes unique technical capabilities to both experiments and the accelerator as well as vital resources.
- US participation in the LHC continues to be a successful example of U.S. reliability in international partnerships.
  - It can serve as a stimulus and model of the great mutual benefits while further partnerships are formulated, such as for the U.S.-hosted neutrino program.
- **The HL-LHC is strongly supported and is the first high-priority large-category project in our recommended program. It should move forward without significant delay to ensure that accelerator and experiments can continue to function effectively beyond the end of this decade and meet the project schedule.**
- **Recommendation 10: Complete the LHC phase-1 upgrades and continue the strong collaboration in the LHC with the phase-2 (HL-LHC) upgrades of the accelerator and both general-purpose experiments (ATLAS and CMS). The LHC upgrades constitute our highest-priority near-term large project.**

ILC (Near-term & Mid-term High-energy Colliders)

- Participation by the U.S. in ILC project construction depends on a number of key factors,
  - some of which are beyond the scope of P5 and
  - some of which depend on budget Scenarios.
- As the physics case is extremely strong, we plan in all Scenarios for ILC support at some level through a decision point within the next five years.
  - If the ILC proceeds, there is a high-priority option in Scenario C to enable the U.S. to play world-leading roles.
  - Even if there are no additional funds available, some hardware contributions may be possible in Scenario B, depending on the status of international agreements at that time.
  - If the ILC does not proceed, then ILC work would terminate and those resources could be applied to accelerator R&D and advanced detector technology R&D.
- **Recommendation 11: Motivated by the strong scientific importance of the ILC and the recent initiative in Japan to host it, the U.S. should engage in modest and appropriate levels of ILC accelerator and detector design in areas where the U.S. can contribute critical expertise. Consider higher levels of collaboration if ILC proceeds.**

Inter-Frontier Connections

Moderator: Yuri Gershtein

Panelists: D. Cowen, R. Henning, B. McKeown, A. Piepke, M. Ramsey-Musolf, R. Roser, J. Yoo

- How do we communicate the importance of neutrino physics to the other Frontiers?
- How do we ensure that “stovepiping” of funding within/between Frontiers doesn’t limit opportunities for science?
- How can we mitigate “stovepiping” within/between HEP and NP (DOE and NSF) that can limit opportunities for science?
- How can we exploit opportunities at the interfaces between the Frontiers?
- How can we exploit connections with nuclear physics?

- **we are *particle physicists*, not neutrino physicists**
- **neutrinos naturally cross many boundaries**
- **funding issues have been solved in the past;
  need constructive solutions in collaboration with agencies**